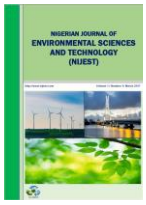
Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2734-259X | ISSN (electronic): 2734-2603
Vol 5, No. 1 March 2021, pp 258 - 270



# Bio-monitoring of Environmental Toxicants using West African Dwarf Goats at Amawzari Mbano, Imo State, Nigeria

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https://doi.org/10.36263/nijest.2021.01.0279

**ABSTRACT**

*Several health risks have been linked to exposure to environmental toxicants in food consume by man. This study aimed to determine the level of environmental toxicants in goats tended by rural farmers. Fur and blood samples were carefully collected from sixteen (16) goats in open range husbandry (ex situ) at four sites in Amawzari, Imo State, Nigeria. The samples were digested and analyzed separately to determine the concentrations of some environmental toxicants (heavy metals). The concentrations of Pb, Cr, Cd and Ni in blood were 0.01 to 0.05, 0.01 to 0.07, 0.00 to 0.01 and 0.05 to 0.12 mg/kg, while their concentration in fur were 0.02 to 0.03, 0.001 to 0.006, 0.00 to 0.00, and 0.04 to 0.05 mg/kg, respectively. Pearson correlation analysis show very strong positive relationship between Pb in blood and Pb in fur ($r = 0.855$, $p < 0.01$) and Ni in blood and Ni in fur ($r = 0.811$, $p < 0.01$). The order of abundance of the four heavy metals tested in goat fur and blood is Ni > Cr > Pb > Cd. Based on our findings, the concentrations of heavy metals in blood were higher than its corresponding values in fur. Thus, consumption of meat processed from these metal-contaminated goats and utilization of their blood to manufacture blood meal for pigs and poultry birds will result to bio-magnification of heavy metals in man and animals. Therefore, we recommend that rural farmers should be enlightened on health challenges associated with in situ form of animal husbandry.*

**Keywords:** Environmental toxicants, Blood, fur, West African dwarf goats, Amawzari

## 1.0. Introduction

The West African Dwarf (WAD) goat is the commonest and most important indigenous goat breed in the 18 countries of West and Central Africa (ILCA, 1987) but Nigeria hosts the largest WAD goat population with approximately 11 million in the humid zone of Eastern Nigeria (Chiejina and Behnke, 2011). It is estimated that at least 90% of these animals are owned by small-holder rural goat keepers, for whom goats represent an important asset (Jabbar, 1998). Goats provide their owners with a broad range of products and socio-economic services such as cash income (meat), security (milk), gifts (skin), and manure for crops (Chiejina and Behnke, 2011). Goats account for about 30% of Africa's ruminant livestock and produce about 17% and 12% of its meat and milk, respectively (Wilson, 2011). Goat is an excellent source of meat called chevron (that is meat from adult goat) which is composed mainly of proteins, fat and some important essential elements and is necessary for growth and maintenance of good health. The protein in goat meat is higher than most of other meats and the fat content is lower than beef or pork (FAO/WHO, 1985).

Goats not only play a vital role in ensuring food security of a household (often being the only asset possessed by a poor household), but when needed and in time of trouble (e.g. crop failure or family illness, school fees), goats may be sold to provide an important source of cash (Peacock, 2005). Any intervention aiming to improve goat productivity will therefore have an immediate socio-economic impact on rural communities, especially the poorest of these for whom goats represent the only livestock they can afford to raise (Chiejina and Behnke, 2011). For about a decade now, factors such as increase in human population, construction of more buildings to ameliorate the challenges of

accommodation, decline in soil fertility among others have resulted to serious short fallow period in South east Nigeria. The cut-and-carry fodder/foliage, which are important ingredients in the husbandry of goats in rural areas is taking tolls on the rural farmers because they spend quantum of time walking distances to collect forage or grasses for their goats that are domesticated in their various homes. This invariably affects other activities embarked by the farmers such as farming, selling of farm products at the market, fetching of water from streams, collection of fuel wood, preparation of food and time spent with their families. Consequently, most livestock farmers resulted to moving their goats to various locations where there are grasses and forage plants. This, however, may expose the domestic animals to the deposition of contaminants on their furs.

The environment is exposed to continuous contamination due to human activities such as industrial production, agricultural processes, mineral exploitation, food processing, commercial, social, and domestic activities (Ogbonna *et al*., 2018). These anthropogenic activities release potential toxic element such as heavy metals into the aquatic and terrestrial ecosystems. For instance, waste water runoff from industries/factories enters fallow/pasture lands as a result of lack of proper drainage system. Indiscriminate discharge of untreated industrial waste water enhances the concentrations of heavy metals in the environment. Particulate matter such as dust and vehicular exhaust smoke contains relative amount of heavy metals that might settle on grasses and fodder plants consume by livestock, thus, contaminating and bio-accumulating in the organs, tissues, and hair/furs of the livestock. Hairs contain sulfhydryl group that can bind toxic element for a long period of time resulting to forgetfulness, nerve damage, lung embolism and bronchitis due to manganese poisoning (Santamaria, 2008). Zinc, lead, aluminum and copper poisoning are implicated for gastrointestinal disorder, ataxia, vomiting, convulsion and paralysis (McCluggage, 1991).

Owing to close association and common environment shared with humans, domestic goats are exposed to similar pollutants and have been suggested as sentinels for biohazards from pollutants (Swarup *et al.,* 2000; Berny *et al.*, 1995). Since furs of domestic goats may accumulate trace elements or heavy metals for a longer period of time and are known to be metabolically inert, it (furs) will serve as an important indicator to determining the level of environmental exposure of goats to heavy metal. Hair tissues analysis has been found to be an excellent tool for monitoring general health and nutritional status for both animals and human (Manson and Zlotkin, 1985; Bhattacharya *et al.,* 2004).

Literature search showed that there is paucity of research carried out on the concentration of heavy metals in goats over the world. These studies are: heavy metals in selected tissues and organs of slaughtered goats from Akinyele Central Abattoir, Ibadan, Nigeria (Oladipo and Okareh, 2015), heavy metals and trace elements in the livers and kidneys of slaughtered cattle, sheep and goats from West of Iran (Bazargani-Gilani *et al*., 2016), survey of trace elements and some heavy metals in goats in Zaria and its environs, Kaduna State (Omoniwa *et al*., 2017). Furthermore, assessment of heavy metals in the blood and some selected entrails of cows, goat and pigs slaughtered at Wurukun abattoir, Makurdi, Nigeria (Ubwa *et al*., 2017), concentration of some heavy metals in the hair, kidney and liver of cattle and goats in the oil and non-oil producing areas of Ondo State, Nigeria (Egigba *et al*., 2018), assessment of heavy metals contents in goat and sheep organs from Ashaka Cements, Gombe State, Nigeria (Chadi and Abdulhameed, 2018) but none of these studies determined the concentrations of potential toxic element in fur and blood in WAD goats. This study, therefore, is aimed to determine the concentrations of heavy metals in fur and blood of WAD goats at open range husbandry (ex situ) in Amawzari Mbano in Imo State, Nigeria. The results of this study will provide baseline information on the level of heavy metals contamination in the WAD goats and possible health hazards associated with consumption of such meat in the area.

## 2.0. Materials and Methods

### *2.1. Study area*

The study was carried out at Amawzari in Isiala Mbano Local Government Area of Imo State, Nigeria (Figures 1 and 2). The headquarters of Isiala Mbano LGA is Umuelemai, and it lies between latitude 5.71°N and longitude 7.18°E on the equator. It is located in the tropical rainforest zone of Nigeria (Keay, 1959). According to the National Population Commission (NPC, 2006) of Nigeria, Isiala Mbano had a population of 198,736.

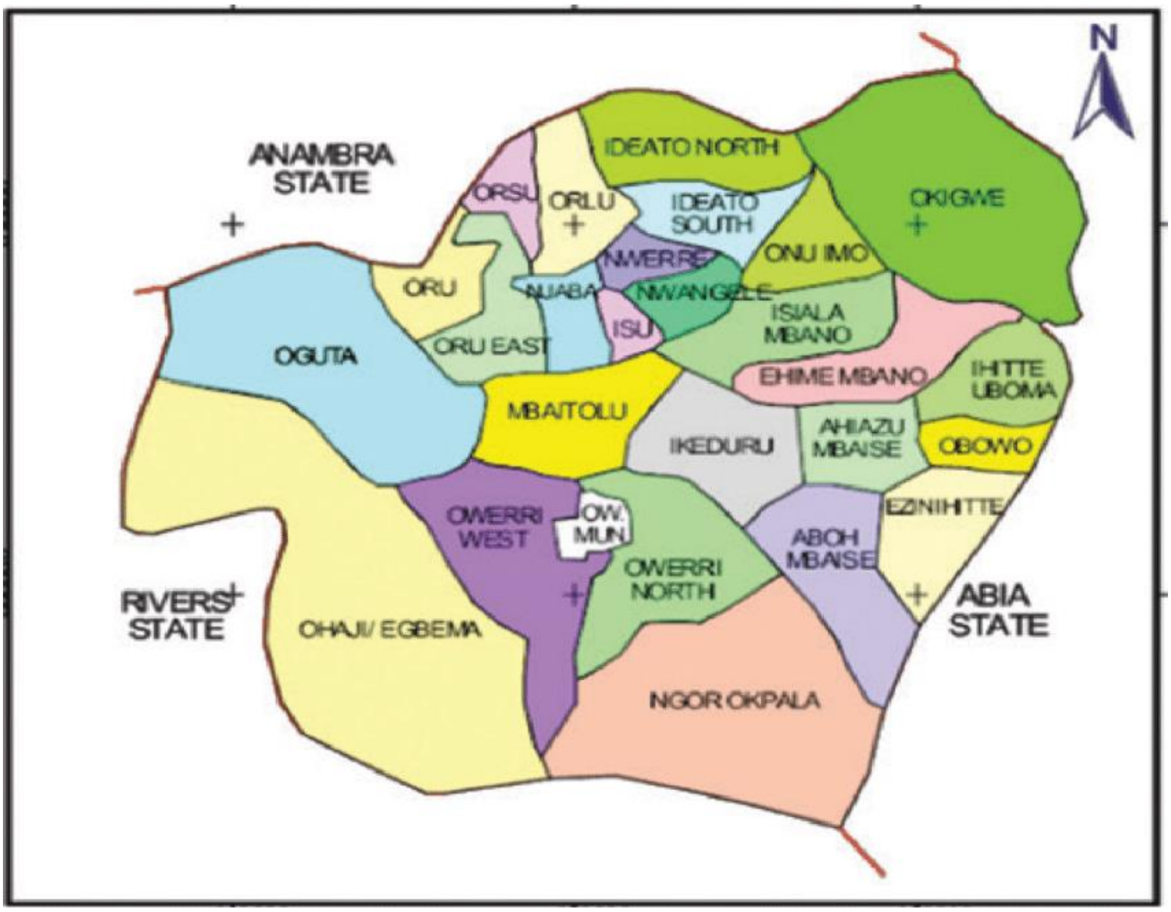


**Figure 1**: Map of Imo State showing Isiala Mbano LGA

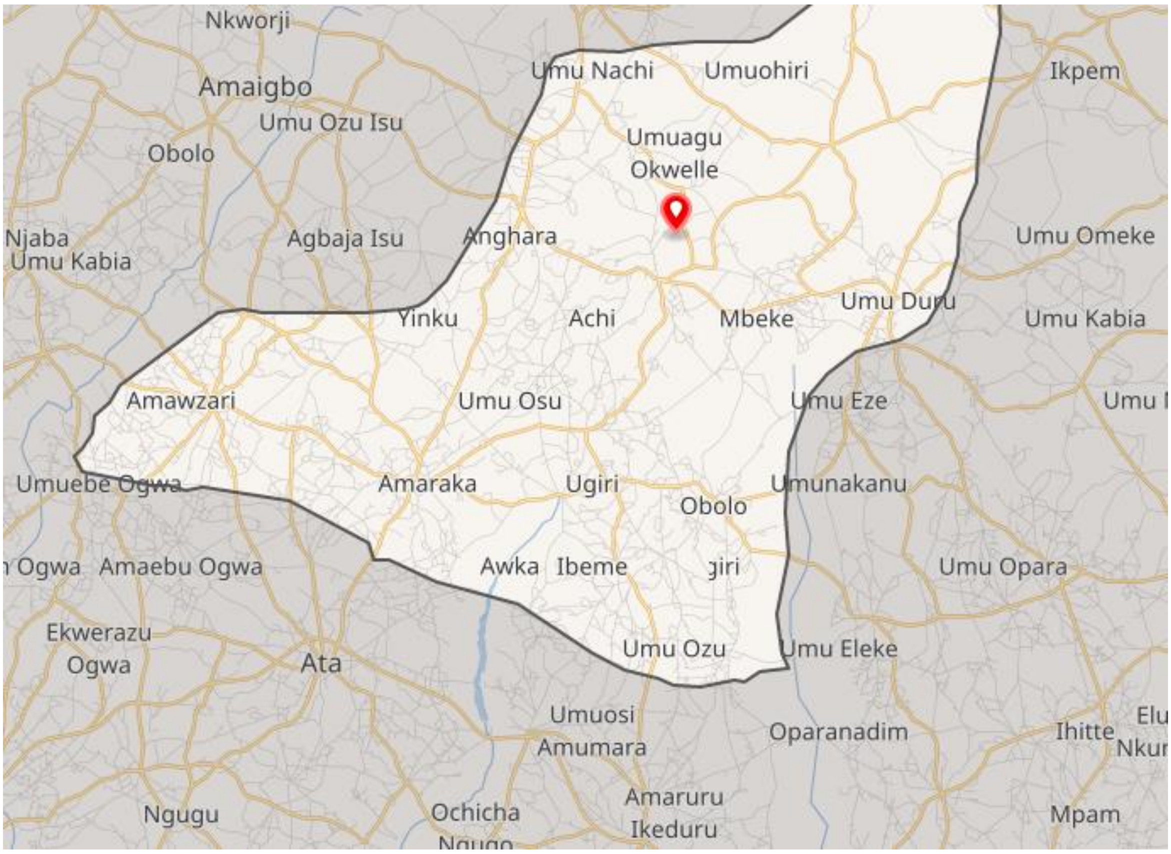


**Figure 2**: Map of Isiala Mbano showing Amawzari

It is bounded on the north by Onuimo Local Government Area and some parts of Nwangele Local Government Area, on the east by Isu and some parts of Nwangele Local Government Areas, on the

south by Ehime Mbano, Ahiazu Mbaise and Ikeduru Local Government Areas, while it has boundary on the west with Ihite Uboma and Obowo Local Government areas. It experience two distinct seasons viz the wet and dry seasons. The dry season begins in November and ends in March while the wet season commence in April and ends in October with peak in July and September. Though, there may be relative break in August, the average annual rainfall is between 1800mm and 2280mm (Warris, 2013). Over the course of the year, the temperature typically varies from 66°F to 87°F and is rarely below 59°F or above 90°F (https://weatherspark.com/y/54991/Average-Weather-in-Umuelemai-Nigeria-Year-Round). The local populace practice subsistence farming that include rearing of domestic livestock especially goats, cultivation of crops such as cassava, maize, yam, cocoyam, plantain, fluted pumpkin, okra, pepper, oil palm trees and fruit trees like *Dacryodes edulis*, *Treculia africana*, *Carica papaya* among others (Field visit).

### *2.2. Sample collection*

Prior to sample collection, reconnaissance survey was carried out to determine the various locations where the farmers tied their goats every morning for preceding three (3) years for foraging. In Amauzari, domestic goats are usually brought out and tied to pole-like stalks to feed in the morning and are taken home in the evenings.

### *2.3. Collection, digestion and analysis of blood sample*

Four (4) locations were used for the study and four goats were selected from each location for sample collection. Fresh blood samples were collected separately from each goat at each location via vein puncture using sterilized syringes. The blood sample from each goat was collected in 25 mL clean sterilized metal-free plastic bottles with gentle handling to prevent hemolysis (Ubwa *et al*., 2017). The sample was placed in icebox and transported to the laboratory. In order to prevent platelet disintegration, it was kept frozen at 4°C in the freezer until the time for pre-treatment and analysis of heavy metals. Samples from each location was thoroughly mixed and homogenized. Sub sample was taken from each homogenized samples for digestion. The wet digestion method of FAO (1990), Licata *et al*. (2004) and Ubwa *et al*. (2017) was adopted with minor modification. About 0.5 mL of the blood sample from each location was predigested with 10 mL 1:1 concentrated $HNO_3$ and $HCLO_4$ acids on a hot plate at 120°C until the liquor had finished undergoing oxidation. Then 5 mL $H_2O_2$ was added and temperature was maintained at 120°C for an hour and 30 minutes until the liquor got completely digested and showed a clear colour. The product of the digestion was allowed to slowly evaporate to near dryness and the digests (blood) was cooled and filtered through Whatman (No. 42) filter paper into 100 mL volumetric flask and made up to the mark with deionized water. Thereafter, determination of the amount of each heavy metal (Pb, Cd, Ni, and Cr) was carried out using Perkin-Elmer analyst 300 Atomic Absorption Spectrophotometer (AAS). The control samples were collected from goat reared indoors (in situ i.e. that are fed and restricted within a hut).

### *2.4. Collection, digestion and analysis of hair*

About 1.5 g hair were collected randomly and separately from different body parts (neck, tail, belly and back) of four (4) goats at each location using well cleaned stainless steel scissors and stored separately in well cleaned zip locks, labeled well and well-sealed, stored in a wooden box to avoid cross contamination from external sources and taken to the laboratory for pre-treatment and analysis. Hairs of goats from each location were bulked together and homogenized. The hair samples were washed briefly with acetone, deionized water, then again with acetone and oven dried at 105°C for 4 hours. Then 1 g of the hair was manually cut to small, homogenized pieces and treated with 10 ml of $HNO_3$, $HClO_4$ and $H_2SO_4$ acid mixture in a ratio of 8:1:1, which was heated to near dryness. The product of the digestion was allowed to slowly evaporate to near dryness. At the end of complete digestion, the digest (hair) was cooled and filtered (Ubwa *et al*., 2017) through Whatman (No. 42) filter paper into 100 ml volumetric flask and made up to mark with distilled water. The control samples were collected from goat reared indoors (i.e. that are fed and restricted within a hut).

### *2.5. Quality assurance and quality control*

For quality assurance and control measures, high purity reagents of analytical grades were obtained from British Drug Houses (BDH) Chemicals Ltd., UK. All plastic and glass containers were cleaned by soaking in dilute $HNO_3$, rinsed in distilled water six times, rinsed in deionized water three times,

oven dried (but for zip locks that were air dried) and cool before use. Reagent blanks and a series of standard solutions of 0.5, 1.0, 2.0, 5.0, 10.0 and 100 mg/l were prepared from the stock standard solution of each test heavy metal by diluting known volumes of the stock solution in 100 ml volumetric flasks using distilled water. The elements that were determined at their various wavelengths were Cr = 283.5, Ni = 221.6, Cu = 766.5, Pb = 220.3, Zn = 213.9, Cd = 228.8, Fe = 510 and Mn = 279.5 nm.

### *2.6. Experimental design and statistical analysis*

A total of sixteen (16) goats were sampled from four (4) different locations in Amauzari (i.e. 4 from each location). The location serves as a block while the four goats from each location are the replicates. The experiment was carried out as a simple factorial in Randomized Complete Block Design (RCBD). The data generated from laboratory analysis were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS), and means were separated with Duncan New Multiple Range Test, DNMRT (Steel and Torrie, 1980).

## 3.0. Results and Discussion

### *3.1. Concentration of environmental contaminants in blood and fur*

The concentrations of environmental contaminants such as heavy metals assessed in the blood of goats are summarized in Table 1. The results indicate that highest and lowest concentrations of the metals were observed in goats at ex situ and in situ (control) sites, respectively. The concentration of Pb were statistically the same at Site 1 (0.05±0.01 mg/kg), Site 2 (0.04±0.01 mg/kg), Site 3 (0.05±0.01 mg/kg) and Site 4 (0.04±0.01 mg/kg) but the values are significantly ($p < 0.05$) higher than the control (0.01±0.00 mg/kg). The high concentration of Pb in goat blood at Sites 1, 2, 3 and 4 may be attributed to high deposition of contaminants (Pb, Cd, Cr and Ni) on grasses and fodders at these locations and subsequent consumption, digestion and assimilation of metals into their blood stream. Studies have shown that grasses, fodders and roughages grown in agricultural sites, industrial areas, and sewer water irrigation fields contain heavy metals (Mora *et al*., 2000; Dietz *et al*., 2001; Rozso *et al*., 2003). The place of animal rearing, dietary habits and exposure time are important factors in heavy metal contamination of livestock (Sabir *et al*., 2003). Inhalation is one of the major entries of heavy metals (Järup, 2003), thus, inhalation is another route of entry of metals into the body of goats in ex situ.

The values of Pb in the blood increased from 0.01 to 0.05 mg/kg which is lower than 0.068±0.0227 mg/l in goat blood at Turkey (Yazar *et al*., 2006), 0.56 mg/l in goat blood at Shagamu, Ogun State (Oluokun *et al*., 2007), 0.259±0.470 mg/l in goat blood at Kaduna State (Omoniwa *et al*., 2017), 5.0867±2.9326 to 7.755±7.4943 mg/kg in goat blood at Zamfara State (Orisakwe *et al*., 2017), 0.411±0.021 mg/kg in sheep blood in China (Shen *et al*., 2019) and 0.31±0.03 mg/kg in human blood at China (Shen *et al*., 2019). Pb has no positive biological function in the growth and development of man. Lead (Pb) is known to alter the hematological system by inhibiting the activities of several enzymes involved in heme-biosynthesis (Okiei *et al*., 2009). Exposure to Pb is considered to be detrimental and associated with behavioral abnormalities, hearing deficits, neuromuscular weakness, and impaired cognitive functions in humans and experimental animals (Flora *et al*., 2012; Assi *et al*., 2016). Acute and chronic lead poisoning contributes in vascular and cardiac damage as well as possible fatal consequences such as cardiovascular illnesses and hypertension (Navas-Acien *et al*., 2007).

The highest concentration of Cr in blood was recorded in goats at Site 1 and the value is significantly ($p < 0.05$) higher than values of Cr obtained in goat blood at Site 2 (0.02±0.01 mg/kg), site 3 (0.02±0.01 mg/kg), site 4 (0.01±0.00 mg/kg), and the control (0.00±0.00 mg/kg). The source of Cr in goat blood may be attributed consumption of fodders, grasses and water contaminated by Cr. Indeed, Imo State is an oil producing State and share boundaries with Rivers State, hence, gas flaring and other industrial activities in Rivers State may result to atmospheric deposition of metals on soil, grasses and water at the study site and subsequent uptake by the goats. The values of Cr in goat blood increased from 0.01 to 0.07 mg/kg which is lower than 0.009 to 0.092 mg/l (Pechova and Pavlata, 2007), 2.7683±0.5477 to 2.9219±1.1640 mg/kg (Orisakwe *et al*., 2017), 0.18 mg/l (Ubwa *et al*., 2017), and 0.072±0.064 mg/l (Omoniwa *et al*., 2017). Chromium cause ulceration and perforation of

the nasal system (Shekhawat *et al*., 2015), acute tubular necrosis, vomiting, abdominal pain, kidney failure and even death (Beaumont *et al*., 2008). Human liver, kidney, spleen and bone have more concentration of Cr in comparison to other organs (NTP, 2008).

**Table 1**: Heavy metals on blood of domestic goat

| Samples | Pb | Cr | Cd | Ni |
|---|---|---|---|---|
| Site 1 | $0.05^{a} \pm 0.01$ | $0.07^{a} \pm 0.02$ | $0.00^{b} \pm 0.00$ | $0.10^{a} \pm 0.01$ |
| Site 2 | $0.04^{a} \pm 0.01$ | $0.02^{b} \pm 0.01$ | $0.00^{b} \pm 0.00$ | $0.10^{a} \pm 0.02$ |
| Site 3 | $0.05^{a} \pm 0.01$ | $0.02^{bc} \pm 0.00$ | $0.00^{b} \pm 0.00$ | $0.10^{a} \pm 0.01$ |
| Site 4 | $0.04^{a} \pm 0.01$ | $0.01^{bc} \pm 0.00$ | $0.01^{a} \pm 0.00$ | $0.12^{a} \pm 0.01$ |
| Control | $0.01^{b} \pm 0.00$ | $0.00^{c} \pm 0.00$ | $0.00^{b} \pm 0.00$ | $0.05^{b} \pm 0.01$ |

*Values are mean ± standard deviation of 3 replicates*

*$^{abc}$ Means in a column with different superscripts are significantly different (P<0.05)*

The highest concentration of Cd in goat blood was obtained in goats at Site 4 (0.01±0.00 mg/kg) and the value is significantly ($p < 0.05$) higher than values obtained at Site 1 (0.00±0.00 mg/kg), Site 2 (0.00±0.00 mg/kg), Site 3 (0.00±0.00 mg/kg) and control (0.00±0.00 mg/kg). The values of Cd in goat blood increased from 0.00 to 0.01 mg/kg which is lower than 0.2433±0.1589 to 0.2835±0.1446 mg/kg (Orisakwe *et al*., 2017), 0.03 mg/l (Jubril *et al*., 2017) and 0.021 mg/l (Skalicka *et al*., 2002) but higher than 0.002 mg/l in goat blood (Or *et al*., 2005) and 0.006±0.004 mg/l in goat blood (Omoniwa *et al*., 2017). Cadmium is of no biological importance to human/animal growth and development. Cadmium causes reductions in both intestinal zinc absorption and hepatic zinc reserves in cattle, respectively, as a result of competition for the cation-binding sites of metallothionein (Orisakwe *et al*., 2017). Exposure to cadmium also affect the function of the nervous system (Vaziri, 2008; Lee *et al*., 2018), with symptoms including headache and vertigo, olfactory dysfunction, Parkinsonian-like symptoms, slowing of vasomotor functioning, peripheral neuropathy, decreased equilibrium, decreased ability to concentrate, and learning disabilities (Abdullahi, 2013). The risk of livestock getting contaminated with heavy metals is a subject of great concern for both food safety and human health because of the toxic nature of metals at relatively minute concentrations (Santhi *et al*., 2008).

The concentrations of Ni in goat blood were statistically ($p > 0.05$) the same in goats sampled from site 1 (0.10±0.01 mg/kg), Site 2 (0.10±0.02 mg/kg), Site 3 (0.10±0.01 mg/kg) and Site 4 (0.12±0.01 mg/kg) but the values are significantly ($p < 0.05$) higher than the value of Ni at the control (0.05±0.01 mg/kg). The values of Ni increased from 0.05 to 0.12 mg/kg which is lower than 0.25 mg/l in goat blood (Yazar *et al*., 2006) and 1.7869±1.6479 to 3.9583±3.0875 mg/kg in goat blood (Orisakwe *et al*., 2017) but higher than 0.03 mg/l (Miranda *et al*., 2005) and 0.05 mg/l (Bernard, 2008). Nickel (Ni) is needed at trace level for normal functioning of the goats. In animals, its deficiency result in depress growth, alterations in carbohydrate and lipid metabolism, delay gestation period, fewer offspring, anaemia, skin eruptions, reduce haemoglobin and hematocrit values, hematopoiesis and alterations in the content of iron, copper, and zinc in liver and reduce activity of several enzymes like hydrogenases, transaminases and α-amylase (Alexandrovn *et al*., 2006; Samal and Mishra, 2011). Notwithstanding this, the lung has been identified as the critical target of nickel toxicity. Nickel substitution for other essential elements may contribute to the adverse health effects of nickel (Al-Ghafari, 2019). The replacement of nickel for magnesium leads to a 40-fold increase in the formation of C3b, Bb enzyme, which amplifies activation of the complement pathway (Orisakwe *et al*., 2017). The order of abundance of the four heavy metals tested in goat blood in this study is as follows: Ni > Cr > Pb > Cd.

The concentrations of heavy metals on fur of goat are presented in Table 2. The results indicate higher concentrations of metals on goats fur at ex situ than that of in situ. The highest concentration of Pb (0.03±0.01 mg/kg) on goat fur was obtained at Site 1 and the value is significantly ($p < 0.05$) higher than values of Pb on goat fur at Site 2 (0.02±0.00 mg/kg), Site 3 (0.02±0.00 mg/kg), Site 4 (0.02±0.00 mg/kg) and control (0.00±0.00 mg/kg). The high value of Pb in goat fur at Site 1 may be as a result of high atmospheric deposition of contaminant (metals) on soil at Site 1 than other sites. The exposure of domestic goats via body contact with (contaminated) soil can be an important route of heavy metal entry (Sabir *et al*., 2003). The concentration of Pb in goat fur increased from 0.02 to 0.03 mg/kg which is lower than 3.76±0.21 reported in sheep wool at China (Shen *et al*., 2019), 0.543±0.062 to 0.649±0.048 mg/kg in fox hair at Poland (Filistowicz *et al*., 2012) and 2.71±0.33 mg/kg in human hair at China (Shen *et al*., 2019) but higher than 0.35±0.09 to 12.0±0.97 µg/g in goat at Egypt (Rasheed and Soltan, 2005).

The concentration of Cr in goat fur was highest in goats sampled at Site 4 (0.006±0.002 mg/kg) and the value is statistically the same ($p > 0.05$) with the concentrations of Pb in goat fur at Site 1 but significantly ($p < 0.05$) higher than values of Cr in goat fur at Site 2 (0.001±0.001 mg/kg), Site 3 (0.001±0.001 mg/kg) and control (0.001±0.001 mg/kg). The concentration of Cr in goat fur increased from 0.001 to 0.006 mg/kg which is relatively higher than 0.04 mg/l reported by Ubwa *et al*. (2017). The concentration of Cd in goat fur are statistically equal ($p > 0.05$) for all the sites (0.00±0.00 mg/kg). The values indicated that the level of Cd at the various sites were very low (Tables 1 and 2). The concentration of Cd on goat fur in this study is lower than 2.28±0.13 mg/kg in sheep wool at Egypt (Shen *et al*., 2019) and 1.88±0.12 in human hair at China (Shen *et al*., 2019).

**Table 2**: Heavy metals on fur of domestic goat

| Samples | Pb | Cr | Cd | Ni |
|---|---|---|---|---|
| Site 1 | $0.03^{a} \pm 0.01$ | $0.004^{ab} \pm 0.004$ | $0.00^{a} \pm 0.00$ | $0.04^{ab} \pm 0.01$ |
| Site 2 | $0.02^{b} \pm 0.00$ | $0.001^{b} \pm 0.001$ | $0.00^{a} \pm 0.00$ | $0.05^{a} \pm 0.03$ |
| Site 3 | $0.02^{b} \pm 0.00$ | $0.001^{b} \pm 0.001$ | $0.00^{a} \pm 0.00$ | $0.05^{a} \pm 0.02$ |
| Site 4 | $0.02^{b} \pm 0.00$ | $0.006^{a} \pm 0.002$ | $0.00^{a} \pm 0.00$ | $0.05^{a} \pm 0.01$ |
| Control | $0.00^{c} \pm 0.00$ | $0.001^{b} \pm 0.001$ | $0.00^{a} \pm 0.00$ | $0.02^{b} \pm 0.00$ |

*Values are mean ± standard deviation of 3 replicates*

[abc] *Means in a column with different superscripts are significantly different (P<0.05)*

The concentration of Ni in goat fur was highest in goats sampled from Site 2 (0.05±0.03 mg/kg), Site 3 (0.05±0.02 mg/kg), Site 4 (0.05±0.01 mg/kg) and Site 1 (0.04±0.01 mg/kg) but the values are significantly ($p < 0.05$) higher than the value observed at the control (0.02±0.00 mg/kg). The concentration of Ni in this study is lower than 0.410±0.264 to 0.560±0.362 mg/kg in fox hair in Poland (Filistowicz *et al*., 2012) but higher than 0.71±0.21 to 2.11±0.98 µg/g in goat hair at Egypt (Rasheed and Soltan, 2005). The order of abundance of the four (4) heavy metals tested in this study that may be causing contamination of fur on goats reared ex situ are as follows: Ni > Cr > Pb > Cd.

Comparatively, the values of heavy metals tested in this study were higher in blood than on fur of the goats at various sites. For instance, the concentrations of Pb, Cr, Cd and Ni were significantly ($p < 0.05$) higher in the blood than on the fur of the goats (Figure 1 to 4). Consequently, the use of such contaminated blood for formation of blood meal for chicken will lead to bio-magnification of these metals vis-à-vis serious health risk to man. Similarly, the consumption of metal-contaminated goat meat will be a route of entry of heavy metals in human alimentary system. The contribution of livestock to food supplies in developing countries is increasing at a higher rate than that of cereals (FAO, 1994).

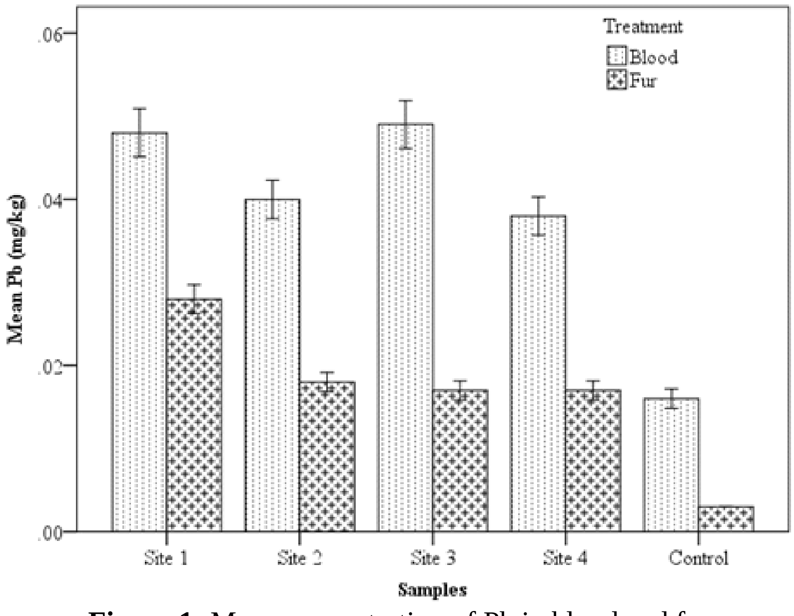


**Figure 1:** Mean concentration of Pb in blood and fur

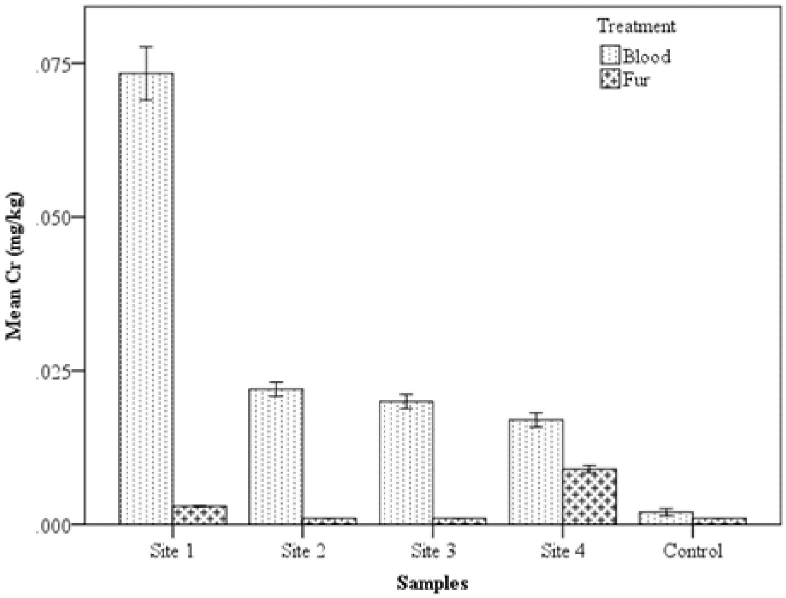


**Figure 2:** Mean concentration of Cr in blood and fur

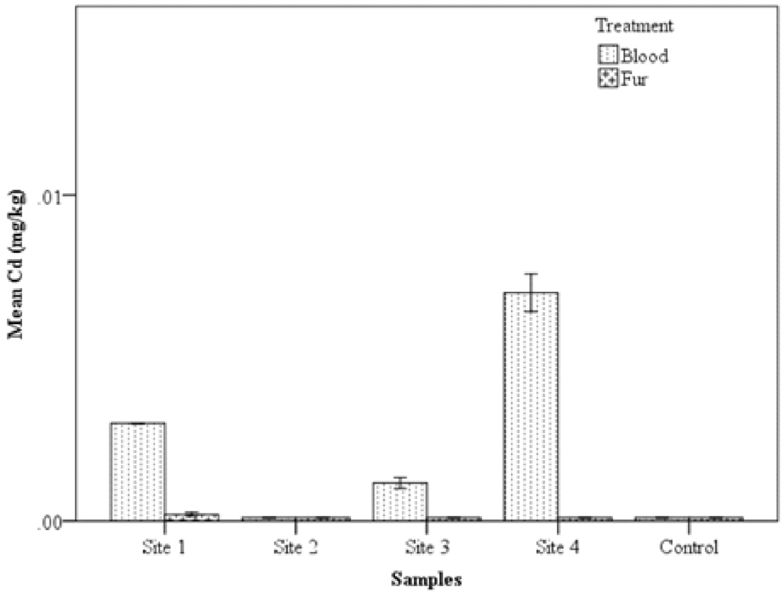


**Figure 3:** Mean concentration of Cd in blood and fur

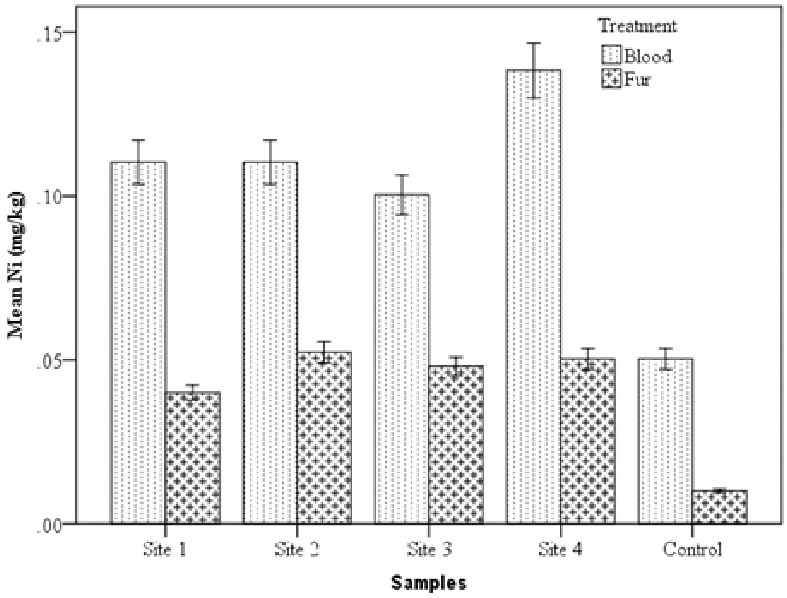


**Figure 4:** Mean concentration of Ni in blood and fur

*3.2. Pearson correlation coefficient of heavy metals in goat blood and fur*

The result of the Pearson correlation analysis of heavy metals in goat blood and fur is summarized in Table 3. The result show very strong positive relationship between heavy metals in blood and fur. For instance, very strong positive relationship exists between Pb in blood and Pb in fur ($r$ = 0.855, $p$ < 0.01) and Ni in blood and Ni in fur ($r$ = 0.811, $p$ < 0.01) which suggest that increase in Pb and Ni in blood might have resulted to their (Pb and Ni) increase in goat fur. Strong positive relationship exist between Pb in blood and Ni in fur ($r$ = 0.585, $p$ < 0.05). Positive relationship exist between Cr in blood and Cr in fur ($r$ = 0.336) and Cd in blood and Cd in fur ($r$ = 0.017). However, there were very strong positive relationship between Cr in blood with Pb in fur ($r$ = 0.685, $p$ < 0.01), Ni in blood with Pb in fur ($r$ = 0.651, $p$ < 0.01) and Cd in blood with Cr in fur ($r$ = 0.756, $p$ < 0.01) while negative relationship occurred between Cr in blood with Cd in fur ($r$ = -0.017), Cr in fur with Cd in fur ($r$ = -0.175) and Cd in fur with Ni in fur ($r$ = -0.145).

**Table 3:** Correlation between heavy metals in blood and fur

| | Pb (blood) | Cr (blood) | Cd (blood) | Ni (blood) | Pb (fur) | Cr (fur) | Cd (fur) | Ni (fur) |
|---|---|---|---|---|---|---|---|---|
| Pb (blood) | 1 | | | | | | | |
| Cr (blood) | 0.476 | 1 | | | | | | |
| Cd (blood) | 0.155 | -0.017 | 1 | | | | | |
| Ni (blood) | 0.741** | 0.226 | 0.480 | 1 | | | | |
| Pb (fur) | 0.855** | 0.685** | 0.066 | 0.651** | 1 | | | |
| Cr (fur) | 0.167 | 0.336 | 0.756** | 0.439 | 0.188 | 1 | | |
| Cd (fur) | 0.354 | 0.455 | 0.017 | 0.044 | 0.504 | -0.175 | 1 | |
| Ni (fur) | 0.585* | 0.000 | 0.200 | 0.811** | 0.413 | 0.150 | -0.145 | 1 |

** Correlation is significant at 5% (P<0.05)*
*** Correlation is significant at 1% (P<0.01)*

## 4.0 Conclusion

The results of the bio-monitoring survey showed that environmental contaminants such as heavy metals contaminated the blood and fur of goats that were fed ex situ than that of in situ. The order of abundance of heavy metals in blood is: Ni > Cr > Pb > Cd while that of fur is also Ni > Cr > Pb > Cd. The values of highest concentration of heavy metals (Cr, Cd, and Pb) occurred at Sites 1 and 4. The level of Pb and Cd in goat blood is a serious concern to man and animals' health. Continuous consumption of the goats raised ex situ in Amauzari will likely have adverse effects on the people of Mbano Local Government Area. Thus, we recommend periodic monitoring of environmental contaminants in Amauzari since the goats are being sold to hoteliers, used for preparation of stew and sauce during occasions such as chieftaincy titles, child dedications, new yam festival and burial ceremony. Therefore, it is recommended that rural farmers should be informed about the consequences of raising goats ex situ.

**Acknowledgement**

The authors acknowledge the rural goat farmers for given us access to the goats at various sampling sites in this study. The services (statistical analysis of the data) of Mr. Emebu, Prosper Kome are also appreciated.

**Conflict of interest**

There is no conflict of interest associated with this work.

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**Cite this article as:**
Ogbonna P. C., Dikeogu, E. C., Nwankwo, O. U., Kanu, K. C. and Osuagwu E. C. 2021. Bio-monitoring of environmental toxicants using West African dwarf goats at Amawzari Mbano, Imo State, Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 5(1), pp. 258-270. https://doi.org/10.36263/nijest.2021.01.0279